

**Parasitization of the Diamondback Moth,
Plutella xylostella (L.)
(Lepidoptera: Plutellidae), in Hawaii¹**

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ABSTRACT

Field studies were conducted at Pulehu, Maui, to determine parasitoid species attacking diamondback moth (DBM), *Plutella xylostella* (L.), on cabbage in 1984 and 1985. *Cotesia plutellae* (Kurdjumov) (Hymenoptera: Braconidae) and *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae) were the predominant parasitoids reared from DBM larvae. Total percentage parasitism at Pulehu varied from 0 to 59%.

Surveys taken in 1986-87 at 6 sites in Hawaii on various crops showed that *C. plutellae* was widely established in the major vegetable growing areas of the state. *D. insulare* was recovered only from those sites greater than 780 m in altitude.

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is a major pest of cabbage and other cole crops in Hawaii (Tabashnik et al. 1987). Studies in Hawaii have shown that cabbage can successfully be produced when DBM densities remain below 0.5 larvae per plant throughout the crop cycle (W. C. Mitchell, unpublished data). Many growers routinely apply insecticides to maintain DBM and other lepidopterous pest densities at sub-economic levels. However, sole dependence on chemical controls can lead to insecticide resistance in DBM (Georghiou 1981, Liu et al. 1981). Relatively few compounds (i.e., fenvalerate) effectively control DBM in Hawaii and development of insecticide resistance management programs are underway (Tabashnik et al. 1987). Simulation studies by Tabashnik (1986a) suggest that reduction of pesticide applications for DBM could prolong the efficacy of fenvalerate. Insecticide resistance management may be partially achieved by utilization of natural enemies during periods in the crop cycle when relatively high levels of DBM damage can be tolerated (i.e., prior to formation of the cabbage head) (Tabashnik 1986b). Toscano et al. (1982) found that higher levels of lepidopterous larval feeding on lettuce could be tolerated between thinning of seedlings and rosette formation as compared with those periods prior to thinning and after rosette formation.

In 1917, the DBM parasitoid *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae) was reported in Hawaii as the immigrant species

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Angitia polynesialis (Cameron) (Timberlake 1918). Although this species has been reported as a major parasitoid of DBM in the continental United States and Canada, it did not maintain DBM densities at sub-economic levels in Hawaii. Because biological control provided by the immigrant race of *D. insulare* was inadequate, the Hawaii Department of Agriculture (HDOA) imported and released individuals of *D. insulare* from Kenya in 1953 (HDOA, unpublished data). The addition of the Kenyan race did not result in successful biological control. Thus, HDOA attempted to increase the number and diversity of natural enemies attacking DBM by introducing several species of hymenopterous parasitoids including *Diadromus* (= *Thyraeella*) *collaris* (Gravenhorst) (Ichneumonidae) and *Cotesia* (= *Apanteles*) *plutellae* (Kurdjumov) (Braconidae) from 1972 to 1985 (Davis 1974, Lai and Funasaki 1986). Although *C. plutellae* has been released at numerous locations throughout the state since 1972, establishment was not achieved until 1982 (Lai and Funasaki 1985). Successful integration of chemical and biological controls for effective resistance management requires knowledge of the impact of established natural enemies on DBM.

The objective of this study was to determine the impact of natural enemies on the DBM in the Kula area of Maui and to identify parasitoid species attacking DBM at various localities in Hawaii.

MATERIALS AND METHODS

Long Term Studies

Field studies were conducted at the Pulehu section of the University of Hawaii Kula Branch Experiment Station, Maui, Hawaii during 1984 and 1985. Cabbage plantings were established by transplanting seedlings at a density of 5,386 plants/ha on 21 March, 3 July, and 26 November 1984. All plantings were 15.2 × 24.4 m (0.04 ha) in size and grown according to local practices except no insecticides were applied.

March 1984, July 1984, and November 1984 plantings were monitored weekly for DBM larvae and pupae from 10 April to 25 May 1984, 9 July to 23 August 1984, and 5 December 1984 to 1 February 1985, respectively. On most survey dates, numbers of all immature stages, except eggs, of lepidopterous species on 100 randomly selected plants were recorded. In the April - May study only 32 plants were sampled on 11 April. Fifty plants were sampled on 22 August in the July - August study and on 16, 23, and 30 January in the December - January study. All individuals collected were taken to the laboratory and held at 26 ± 1° C until adult stages of the lepidopterous species or parasitoids emerged. Studies were continued until cabbage heads were ready for harvest.

Parasite identifications were confirmed by John W. Beardsley, Department of Entomology, University of Hawaii. Percent parasitism was calculated by dividing the total number of parasitoids reared by the sum of the DBM adults and total number of parasitoids reared.

Individual Sites

In 1986, DBM larvae were collected from cabbage plantings at Kamuela, Hawaii; Kula and Pulehu, Maui; and Waimanalo, Oahu. Immature DBM stages were also collected from daikon, bok choy, and watercress plantings at Hawaii Kai and Kahuku, Oahu, and Kapaa, Kauai, respectively. In 1987, DBM larvae were collected on cabbage at Waimanalo, Oahu. Larvae were taken to the laboratory where they were placed in plastic containers $17.2 \times 29.0 \times 7.7$ cm and provided cabbage leaves. Containers were held at $27.5 \pm 0.5^\circ$ C and checked daily for either parasitoid or DBM pupation. Parasitoids were reared to the adult stage and identified. Percent parasitism was calculated by dividing the number of parasitoid pupae reared by the total number of DBM larvae initially collected.

RESULTS AND DISCUSSION

Long Term Studies

In each planting, DBM was the predominate pest species found and densities varied throughout the crop cycle. Additional lepidopterous species collected were cabbage looper, *Trichoplusia ni* (Hübner) (Noctuidae), imported cabbageworm, *Artogeia rapae* (L.) (Pieridae), and cabbage webworm, *Hellula rogatalis* (Hulst) (Pyralidae). For the purposes of this study, discussion will be limited to DBM.

Hymenopterous parasitoids reared from DBM larvae were *D. insulare*, *C. plutellae*, *Pristomerus hawaiiensis* Perkins (Ichneumonidae), and *Chelonus blackburni* Cameron (Braconidae).

In the April - May study, DBM larval densities were initially 1.56 larvae/plant on all survey dates except Dec. 5 (Fig. 3a). Percentage parasitism was low (< 10%). Larvae were predominately parasitized by *D. insulare* and *C. plutellae*. Individuals of *P. hawaiiensis* Perkins and *Chelonus blackburni* were reared in low numbers (< 6) from DBM larvae. Percentage parasitism varied from 0 to 60% during the season (Fig. 1b). *D. insulare* was the major parasitoid reared and appeared to regulate the DBM population (Fig. 1b). *C. plutellae* densities remained low (< 0.07 parasites/plant) throughout the season and probably contributed little to DBM control.

In the July - August study, DBM population densities increased from 0.08 larvae/plant to 2.03 larvae/plant from 11 July to 1 August, respectively (Fig. 2a). After declining on 8 August, larval densities again increased to 5.66 larvae/plant on 22 August. Percentage parasitism remained low (< 20%) throughout most of the study. *C. plutellae* was the predominant parasitoid and densities of *D. insulare* were extremely low (< 0.12 parasites/plant) (Fig. 2b).

The December - January planting had between 1.0 and 2.1 DBM larvae/plant on all survey dates except Dec. 5 (Fig. 3a). Percentage parasitism ranged from 29 to 51%. *C. plutellae* was the predominant parasite with low densities (< 0.15 Parasites/plant) of *D. insulare* (Fig. 3b).

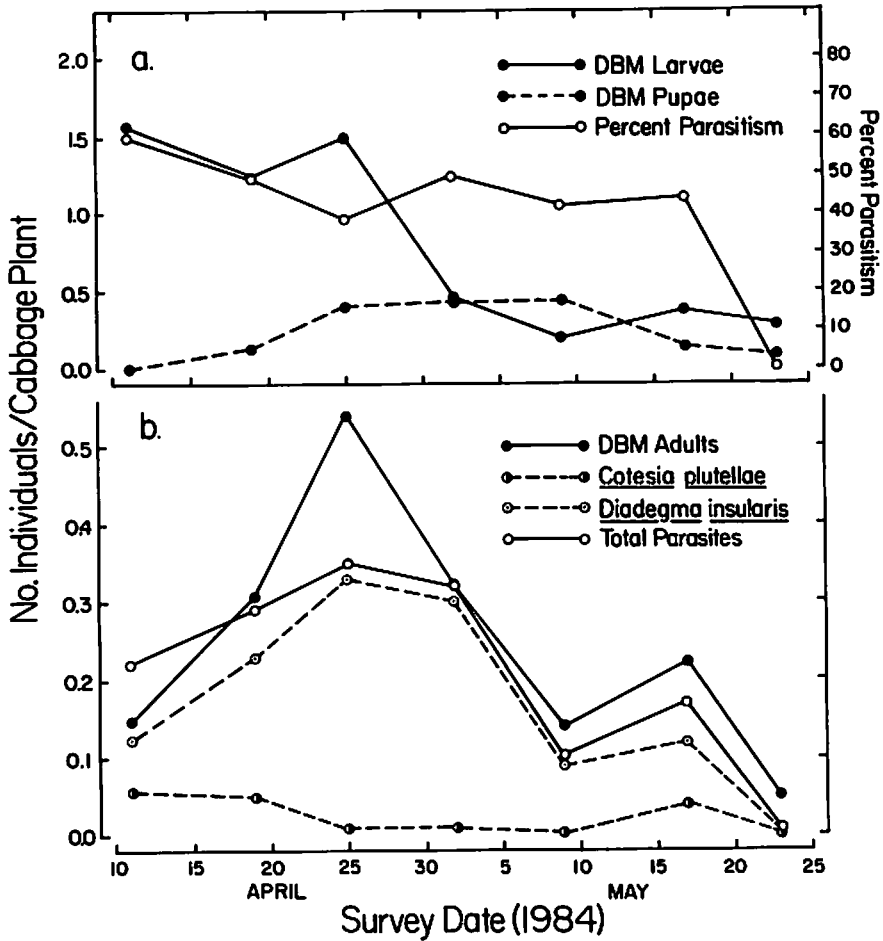


FIGURE 1. Diamondback moth (DBM) larval and pupal densities and percentage larval parasitism (a); and densities of DBM adult and parasites reared from DBM larvae collected on cabbage (b) at Pulehu, Maui, during April and May 1984.

Individual Sites

Parasites reared from DBM collected at various sites were *C. plutellae* and *D. insulare*. Total percentage parasitism varied from 3.6 to 73.2% (Table 1). *C. plutellae* was common in all locations and crops surveyed. *D. insulare* was found only at Kula, Maui, and Kamuela, Hawaii. It is interesting that *D. insulare* was collected only at those sites greater than 780 m in altitude where temperatures would be cooler on the average as compared with the other sites which were less than 80 m in altitude.

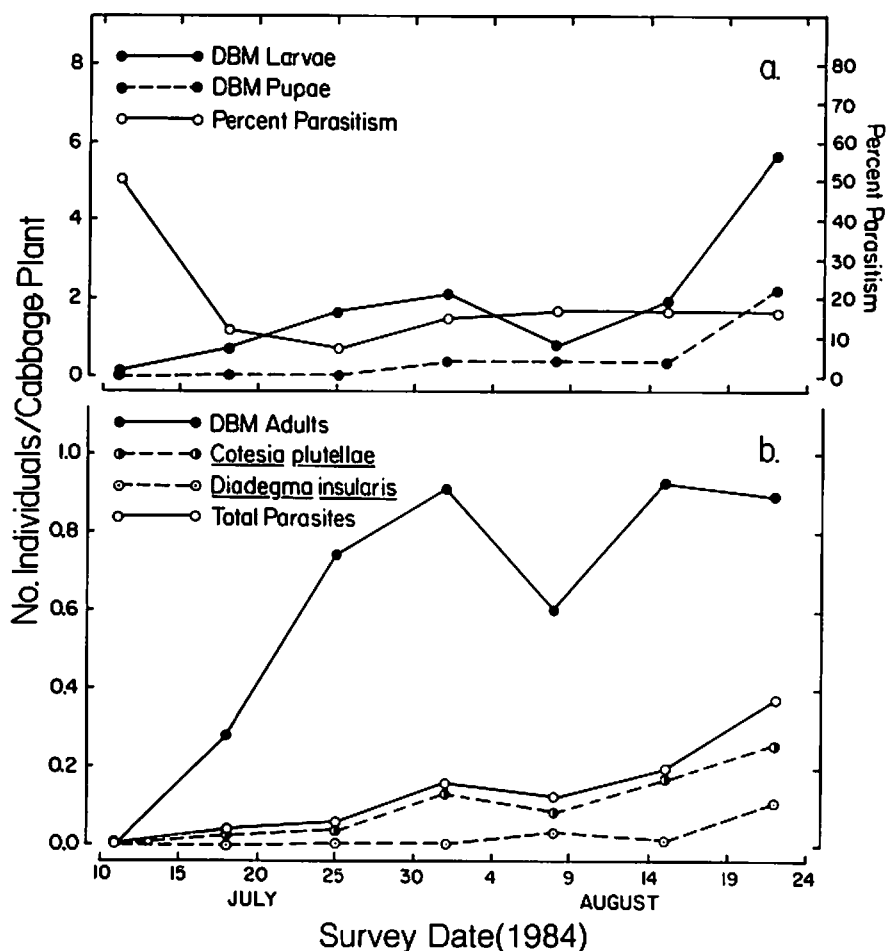


FIGURE 2. Diamondback moth (DBM) larval and pupal densities and percentage larval parasitism (a); and densities of DBM adult and parasites reared from DBM larvae collected on cabbage (b) at Pulehu, Maui, during July and August 1984.

CONCLUSIONS

D. insulare appeared to play an important role in regulating DBM densities at Pulehu in April and May. However, its densities never surpassed those of *C. plutellae* in the latter two studies. *C. plutellae* has become established in the major vegetable production areas in Hawaii. However, complete biological control of DBM has not been achieved to date because pest densities still remain above economically tolerable levels. Insecticide

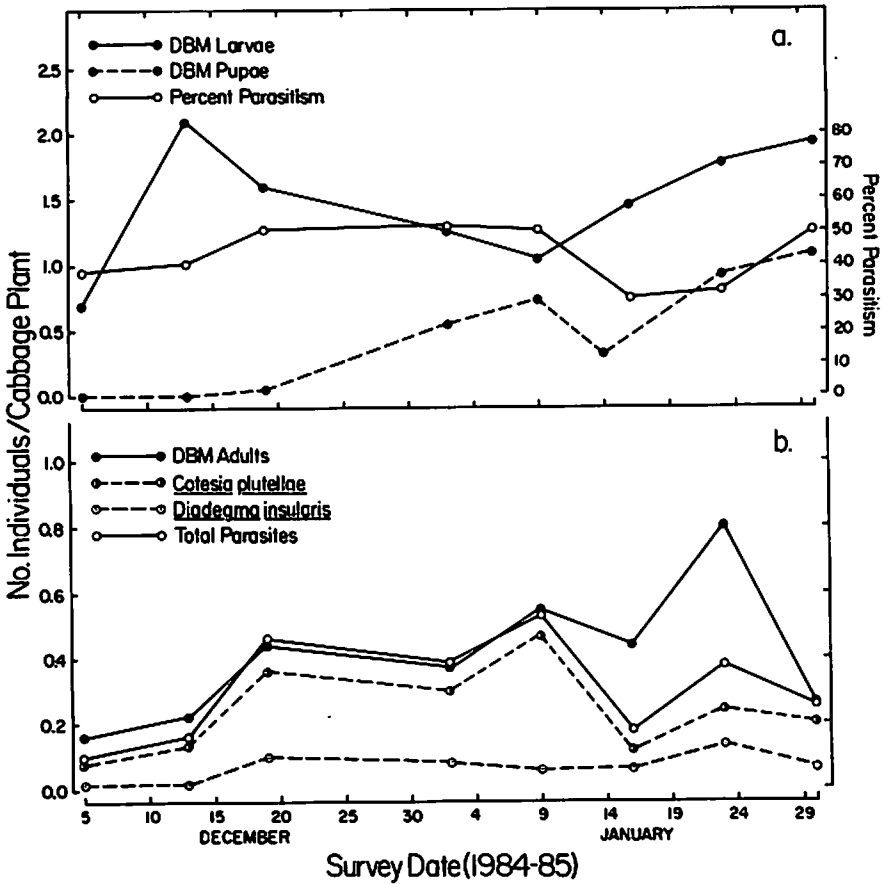


FIGURE 3. Diamondback moth (DBM) larval and pupal densities and percentage larval parasitism (a); and densities of DBM adult and parasites reared from DBM larvae collected on cabbage (b) at Pulehu, Maui, during December 1984 and January 1985.

resistance management could possibly be achieved through use of economic thresholds and biotic larvicides (i.e., Dipel) which would reduce pesticide use and provide an opportunity for parasitoids to partially suppress DBM populations.

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TABLE 1. Numbers of DBM larvae and parasites collected at various sites in Hawaii in 1986 and 1987.

Site	Sample	Crop	No. DBM	No. Parasitoids Reared		Total% Parasitism
	Date			Larvae	<i>Cotesia plutellae</i>	
Hawaii 1986						
Kamuela	23 June	Cabbage	90	20	28	53.3
Kauai 1986						
Kapaa	25 July	Watercress	275	32	0	11.6
Maui 1986						
Pulehu	15 Dec	Cabbage	120	11	0	9.2
Kula	15 Dec	Cabbage	225	27	19	20.4
Oahu 1986						
Hawaii Kai	30 June	Daikon	25	9	0	36.0
	16 July	Daikon	45	23	0	51.1
Kahuku	13 August	Bok Choi	437	197	0	45.1
Waimanalo	20 May	Cabbage	97	71	0	73.2
Oahu 1987						
Waimanalo	11 Feb	Cabbage	502	18	0	3.6

REFERENCES CITED

- Davis, C. J. 1974. Recent introductions for biological control XVIII. Proc. Hawaii. Entomol. Soc. 21: 355-358.
- Georghiou, G. P. 1981. The occurrence of resistance to pesticides in arthropods. FAO, Rome. 172 pp.
- Lai, P. Y., and G. F. Funasaki. 1985. Introductions for biological control in Hawaii, 1981 and 1982. Proc. Hawaii. Entomol. Soc. 25: 83-86.
- _____. 1986. Introductions for biological control in Hawaii: 1983 and 1984. Proc. Hawaii. Entomol. Soc. 26: 89-91.
- Liu, M. Y., Y. J. Tzeng, and C. N. Sun. 1981. Diamondback moth resistance to several synthetic pyrethroids. J. Econ. Entomol. 74: 393-396.
- Tabashnik, B. E. 1986a. A model for managing resistance to fenvalerate in the diamondback moth (Lepidoptera: Plutellidae). J. Econ. Entomol. 79: 1147-1451.
- Tabashnik, B. E. 1986b. Evolution of pesticide resistance in predator-prey systems. Bull. Entomol. Soc. Am. 32: 156-161.
- Tabashnik, B. E., N. L. Cushing, and M. W. Johnson. 1987. Diamondback moth (Lepidoptera: Plutellidae) resistance to insecticides in Hawaii: Intra-island variation and cross-resistance. J. Econ. Entomol. 80: 1091-1099.
- Timberlake, P. H. 1918. Notes on some of the immigrant Hymenoptera of the Hawaiian Islands. Proc. Hawaii. Entomol. Soc. 3: 399-404.
- Toscano, N. C., R. A. Van Steenwyk, K. Kido, N. F. McCalley, W. W. Barnett, and M. W. Johnson. 1982. Yield responses in lettuce plants at various density treatment levels of lepidopterous larvae. J. Econ. Entomol. 75: 916-920.

